Collaborative Aerosol Research

Boston College – Aerodyne

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[3] University of Toronto

DOE Atmosphere Science Program
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Annapolis, MD
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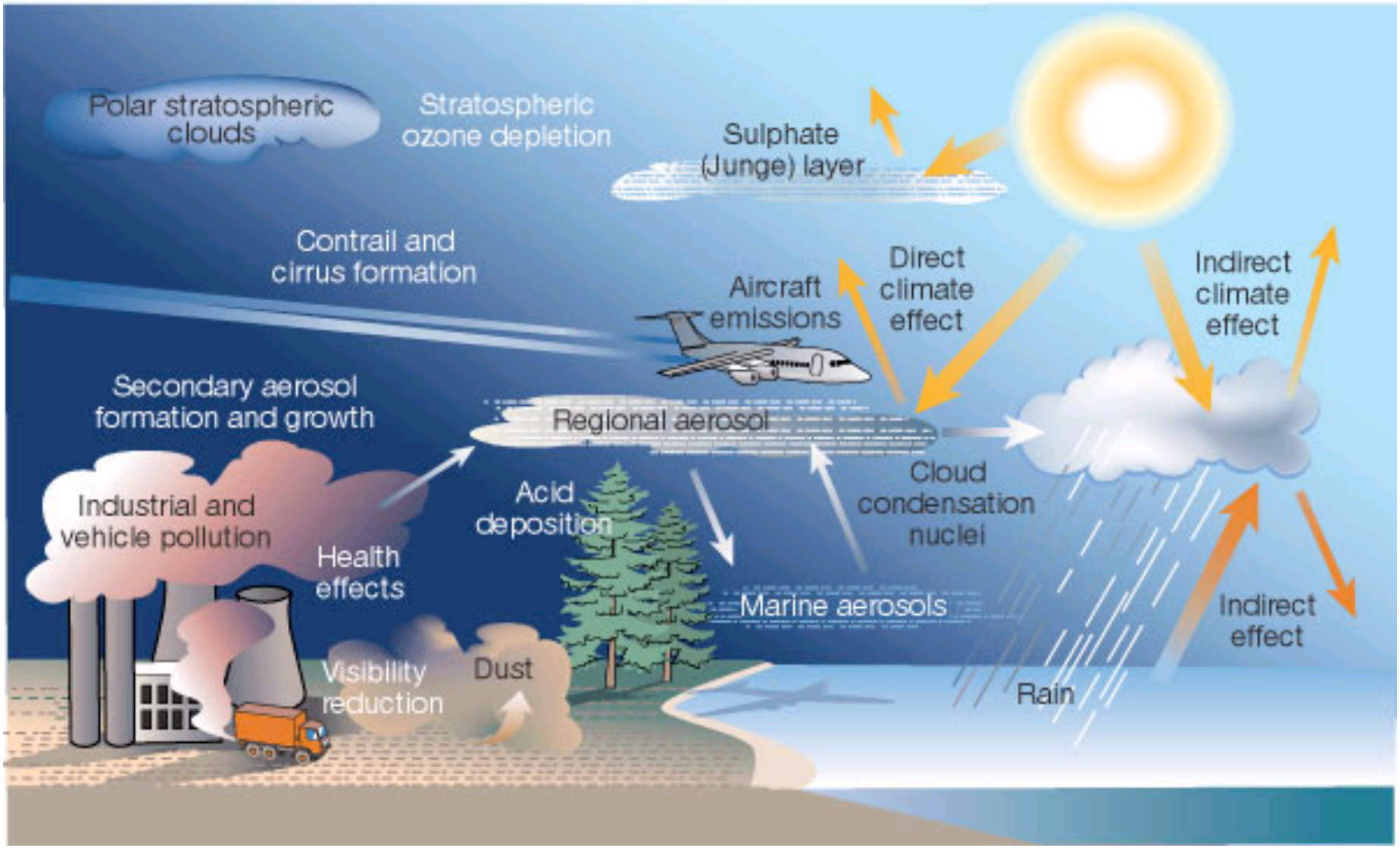
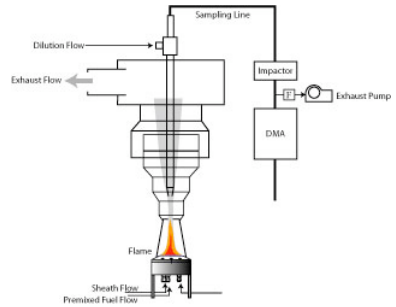
Aerosols in the Atmosphere



C.E. Kolb, **Nature,** 597-598, 6 Jun 2002

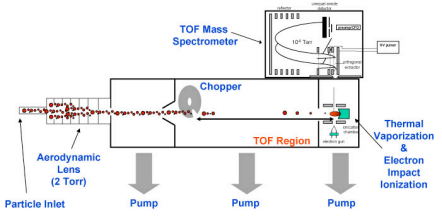
FOCUS: Characterize chemical and physical properties and atmospheric transformations of aerosol particles through laboratory studies and extractive sampling techniques

- **Boston College Laboratory: Carbonaceous aerosol generation, modification, and characterization**
  - Sooting flame generation
  - DMA-AMS, SMPS, and CCN chemical and physical characterization
  - Black carbon instruments comparison studies (e.g. MAAP, SP2, PAS)

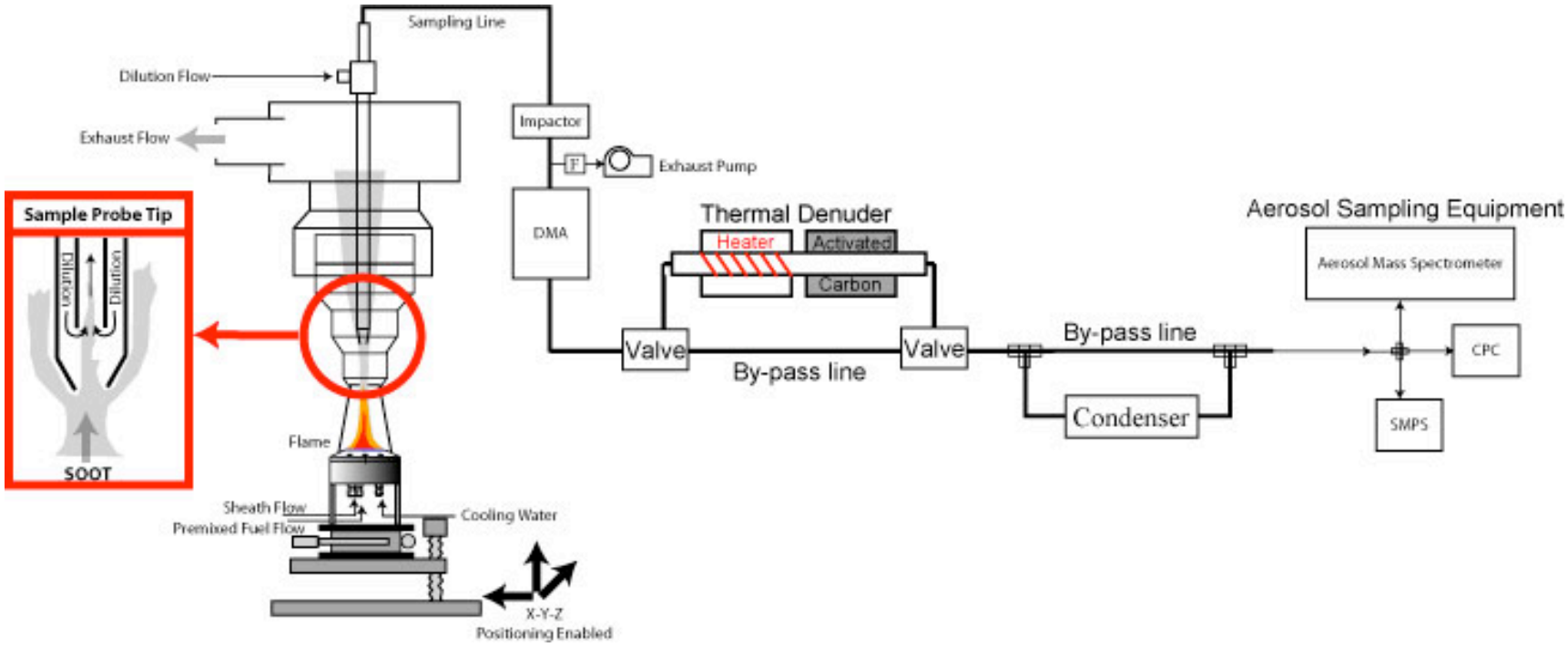


- **Field studies**
  - Mexico City (2002, 2003, 2006)
  - NEAQS (2004)

- **Instrument development and testing**
  - LS-QAMS
  - LS-C-TOF-AMS
  - SP2-AMS

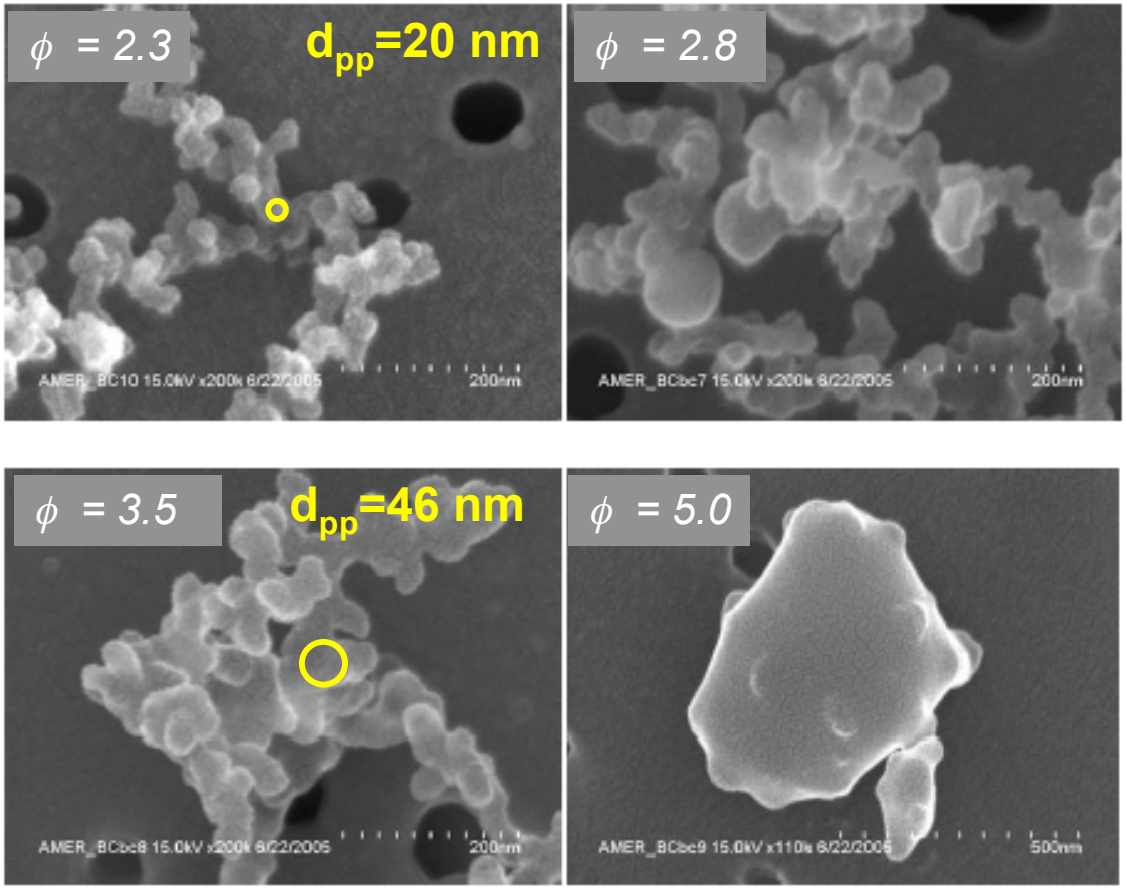


Laboratory: Flame Apparatus



- Premixed flame: fuel-to-air (equivalence) ratio from <1 to > 5 (sooting flame above 1.8)
- Controlled sampling system with reproducible particle generation
- Polydisperse or DMA size-selected soot particles
- Sample flow rates of 0.2 – 4 lpm provided to multiple instruments
- Thermal denuder and Condenser to modify generated soot particles

Monodisperse Soot Generation



Operating Parameters

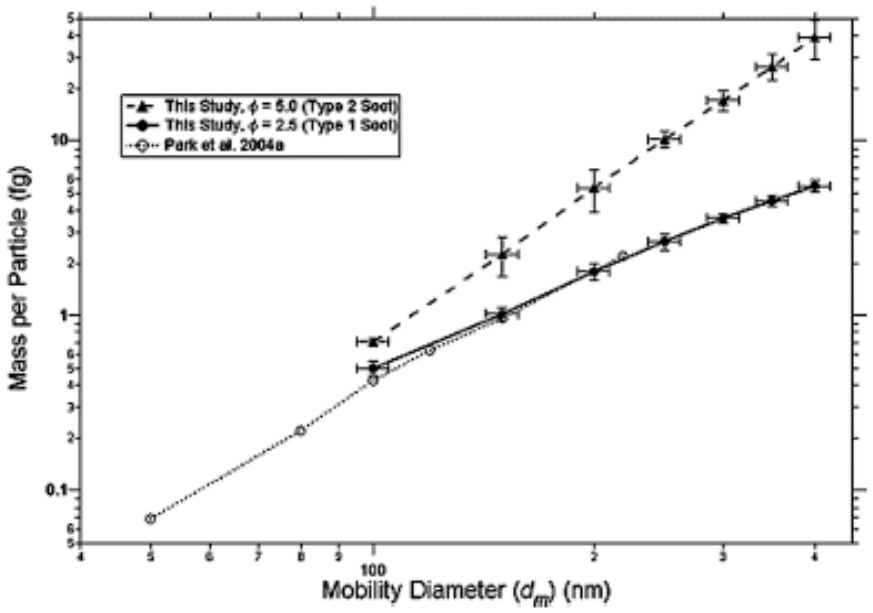
$1.8 < \varphi < 5.0$

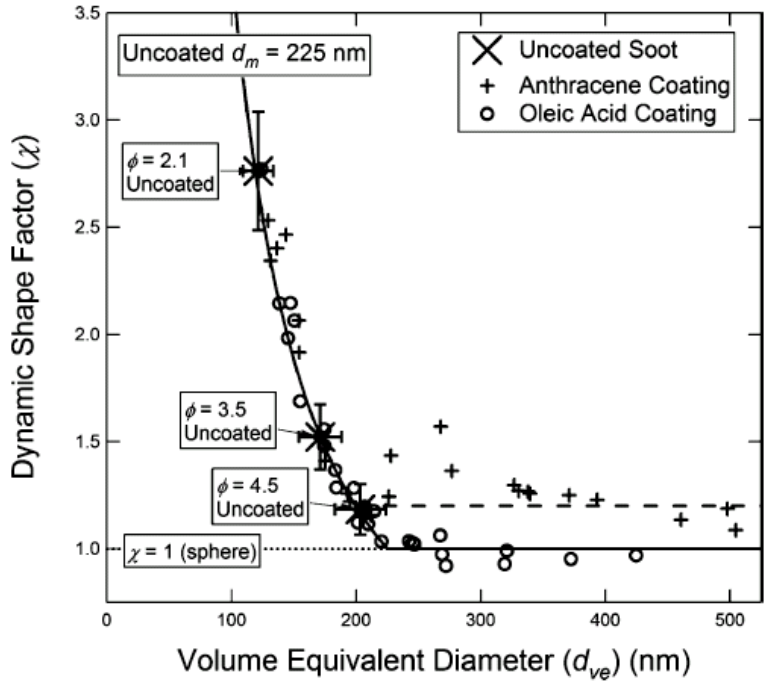
$30 < D_{mobility}(nm) < 500$

$15 < D_{pp}\ (nm) < 55$

$0 <$ Coatings (nm) < 150

Soot Characterization, Coating, and Denuding Experiments





- Particle shape affects size measurements and derived mass measurements
- Results from premixed laboratory flame experiments show behavior similar to diesel soot particles

Slowik, J. G., E. S. Cross, et al. (2007). Aerosol Science and Technology **41**(8): 734-750

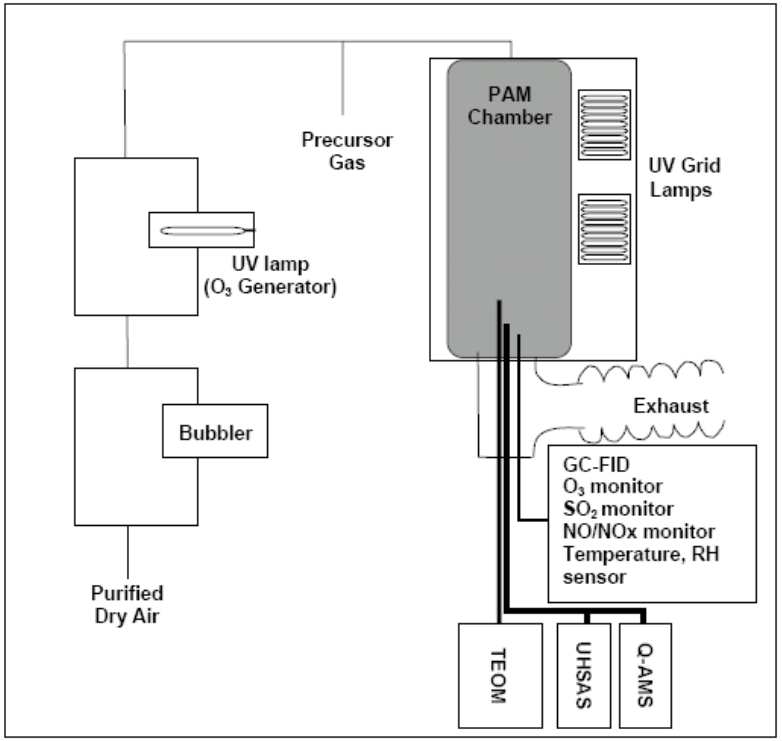
Laboratory and Field: Chemical flow tube

Introducing the concept of Potential Aerosol Mass (PAM)

E. Kang[1], M. J. Root[1], D. W. Toohey[2], and W. H. Brune[1]

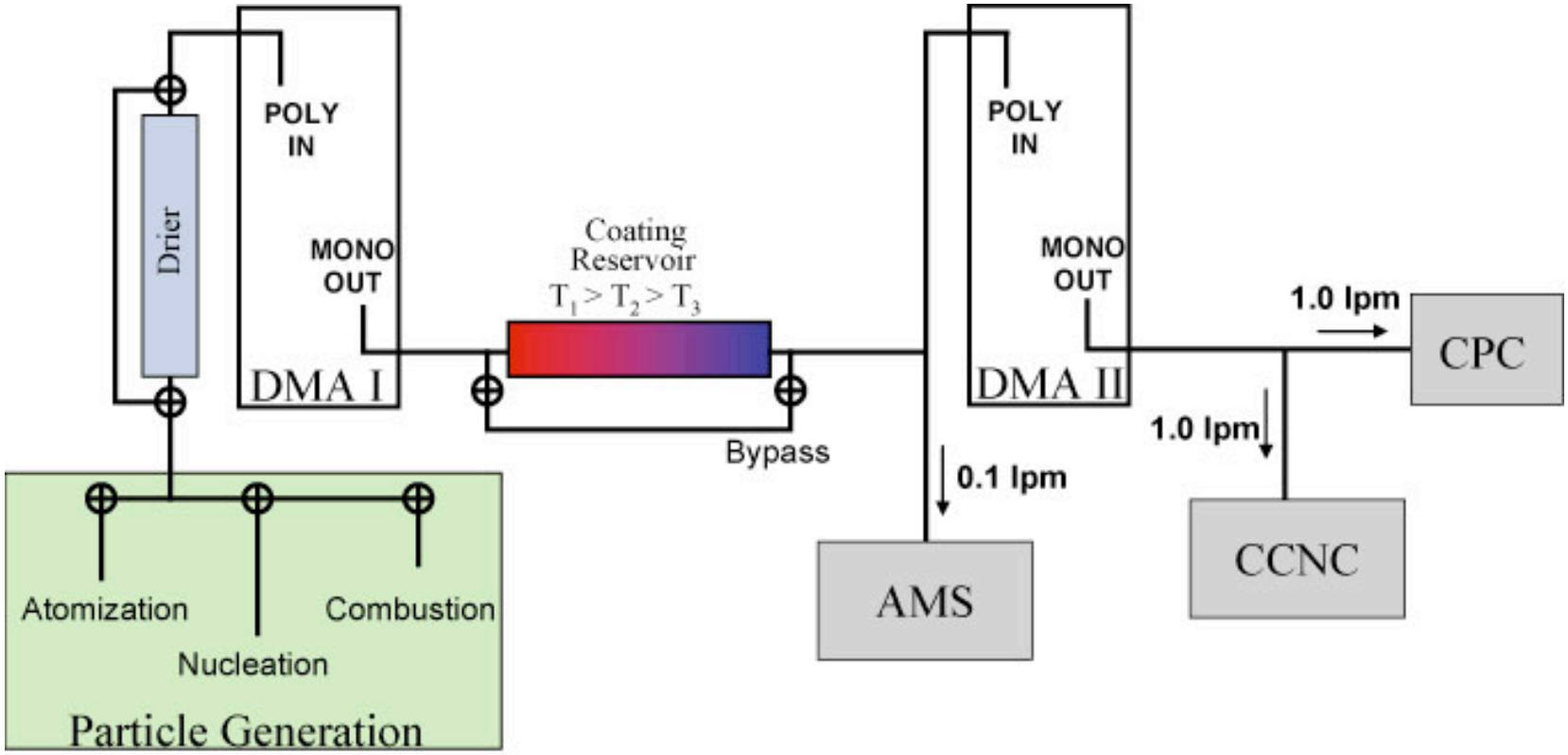
[1]Department of Meteorology, Pennsylvania State University, University Park, PA 16802, USA
[2]Atmospheric and Oceanic Sciences, University of Colorado, CO 80309-0311, USA

Atmos. Chem. Phys., 7, 5727–5744, 2007



- **Collaboration with Prof. Brune in PAM characterization and employment**
- **Characterization of Highly Oxidized Secondary Organic (SOA) Coatings**
- **Specifically looking at AMS mass spectra of organic compounds as a function of oxidation (e.g. OOA2 to OOA1 progression)**

CCN (cloud activation) experiments



- Particles composed of soluble (e.g. ammonium sulfate), slightly soluble (e.g. adipic acid), and insoluble (flame soot) materials

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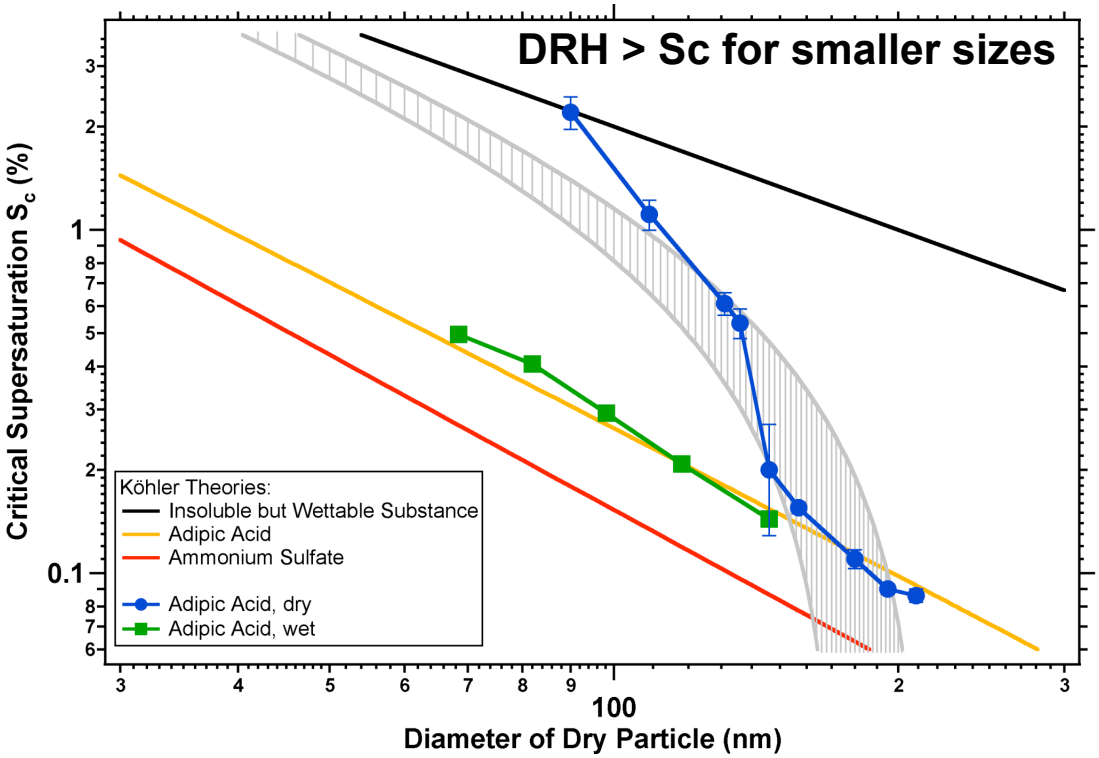
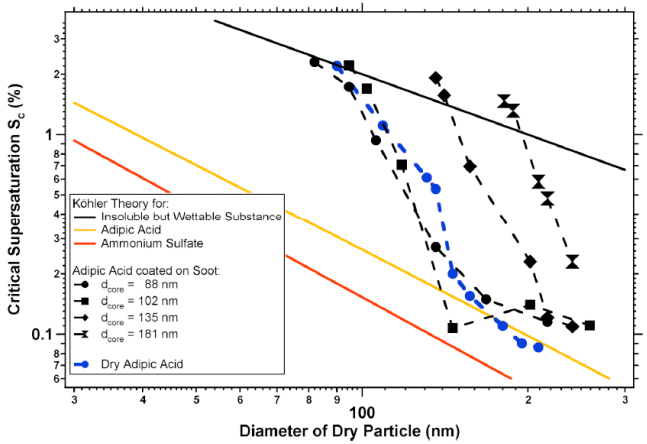
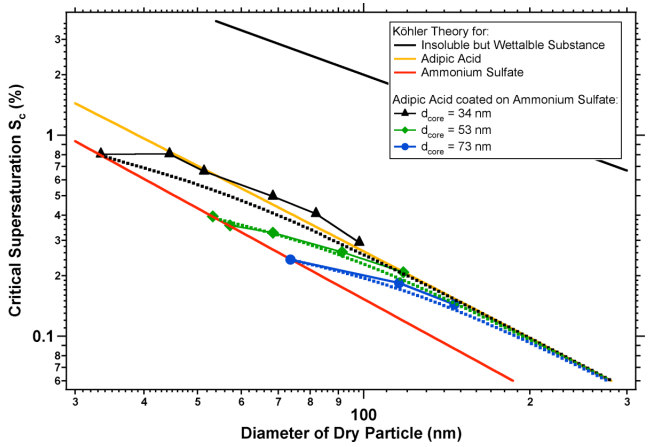
Adipic Acid, Ammonium Sulfate, Soot







- Measuring CCN over large size and SS ranges
- Particle phase is very important for slightly soluble compounds
- Koehler theory works well mixed adipic acid and sulfate particles
- Insoluble soot core acts as support structure for small amounts of adipic acid coating, but larger soot particles may not get fully coated

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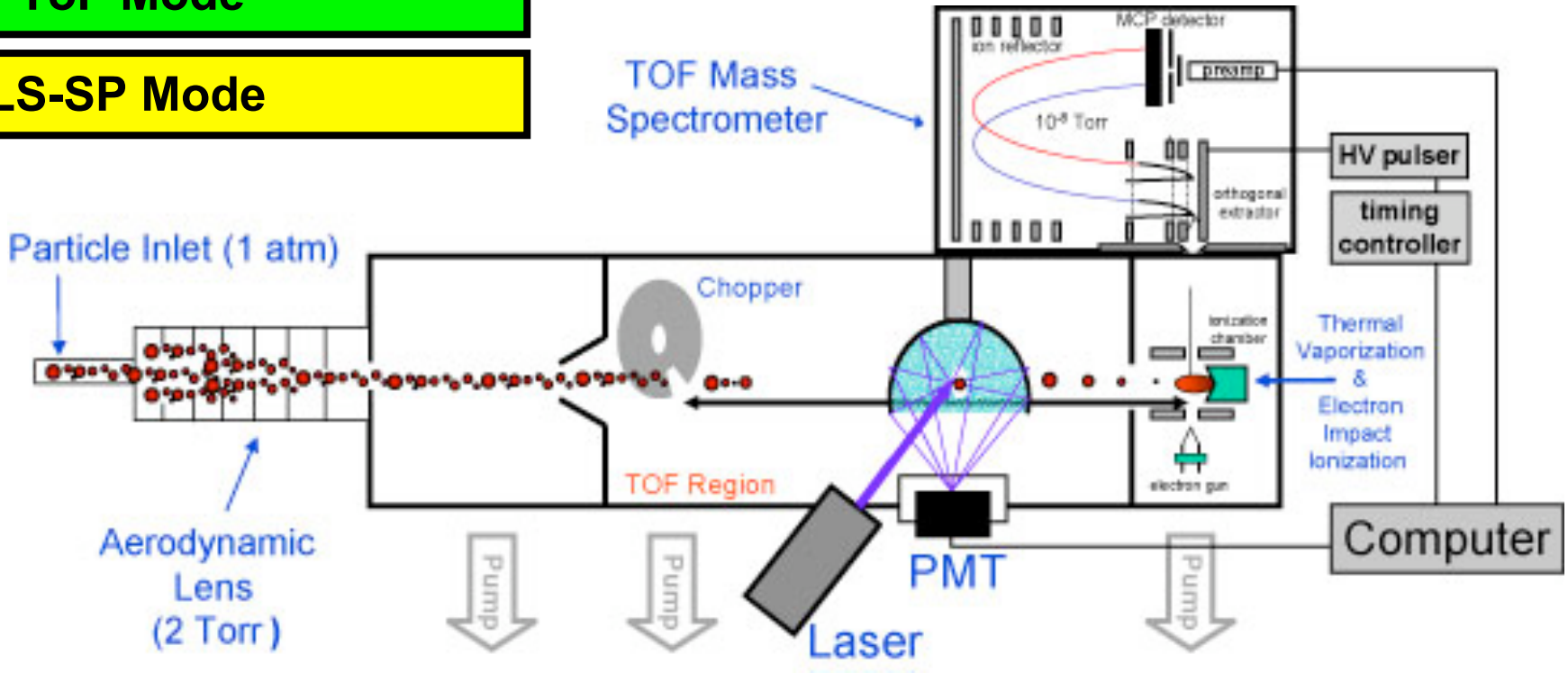
Instrument Development: LS-C-ToF-AMS

MS Mode

PToF Mode

LS-SP Mode



- Practical single particle aerosol mass spectrometer
- Alternating with measurements of ensemble chemistry and size

Cross, E. S., J. G. Slowik, et al. (2007). Aerosol Science and Technology 41: 343-359.

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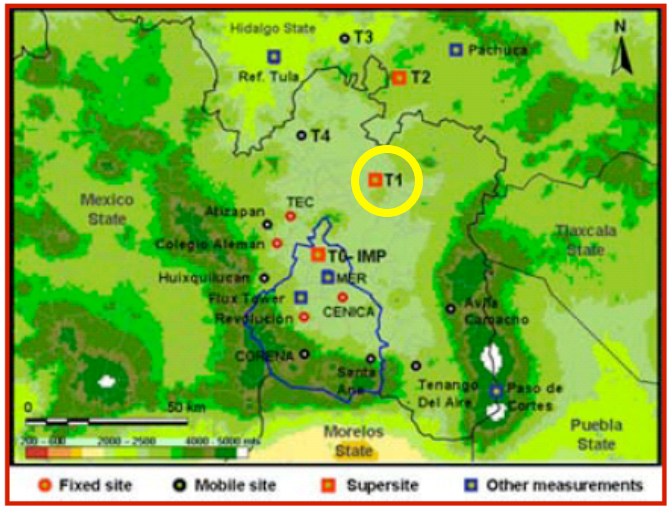
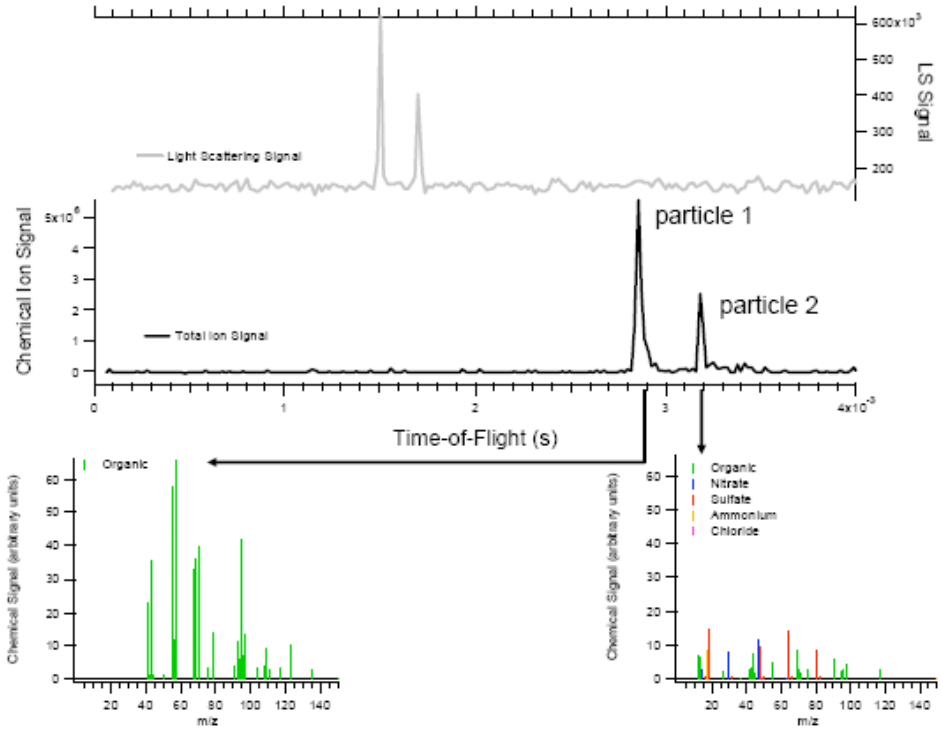
Mexico City Field Deployment



http://mce2.org/megacities/fieldcampaign2006/



- LS-C-TOF-AMS operated for 74 hours at the T1 site NE of Mexico City
- Measured single particle mixing states while contemporaneously measuring ensemble chemistry and size

in collaboration with Liz Alexander (EMSL, PNNL)

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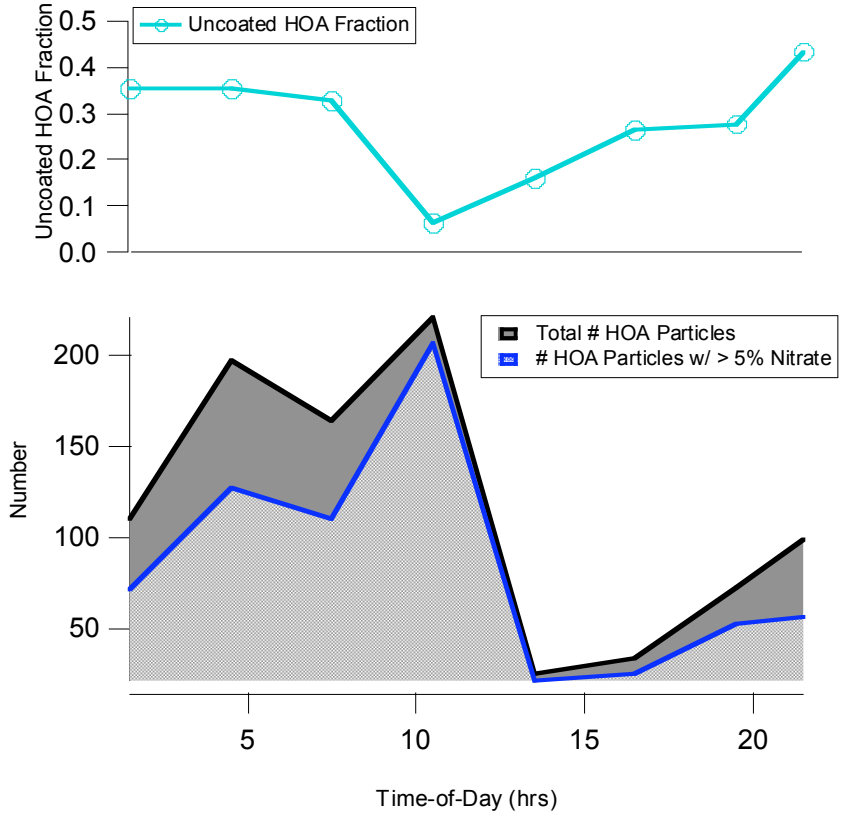
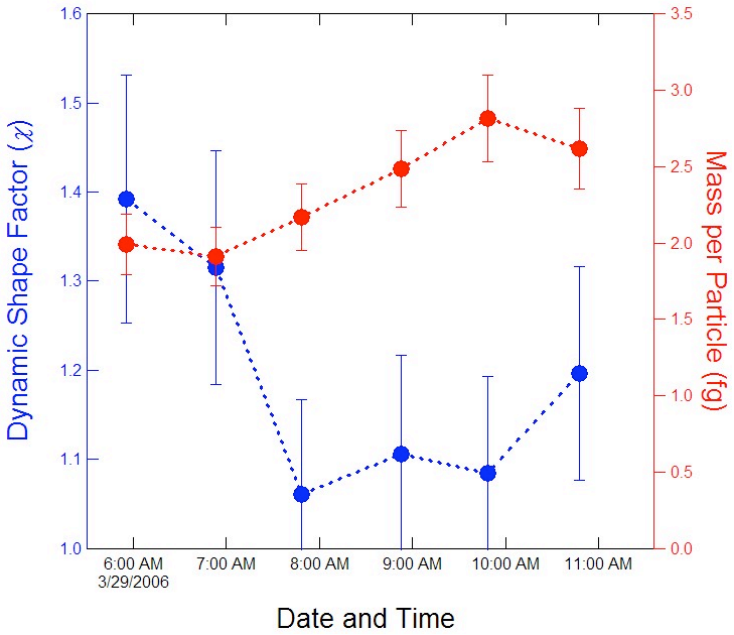
Direct Observations of Condensation onto Fresh Soot Particles

T1: LS-C-TOF-AMS



T0: DMA-AMS



- Single particle detection of secondary oxidation products (NO3 and SOA) condensing on primary HOA particles

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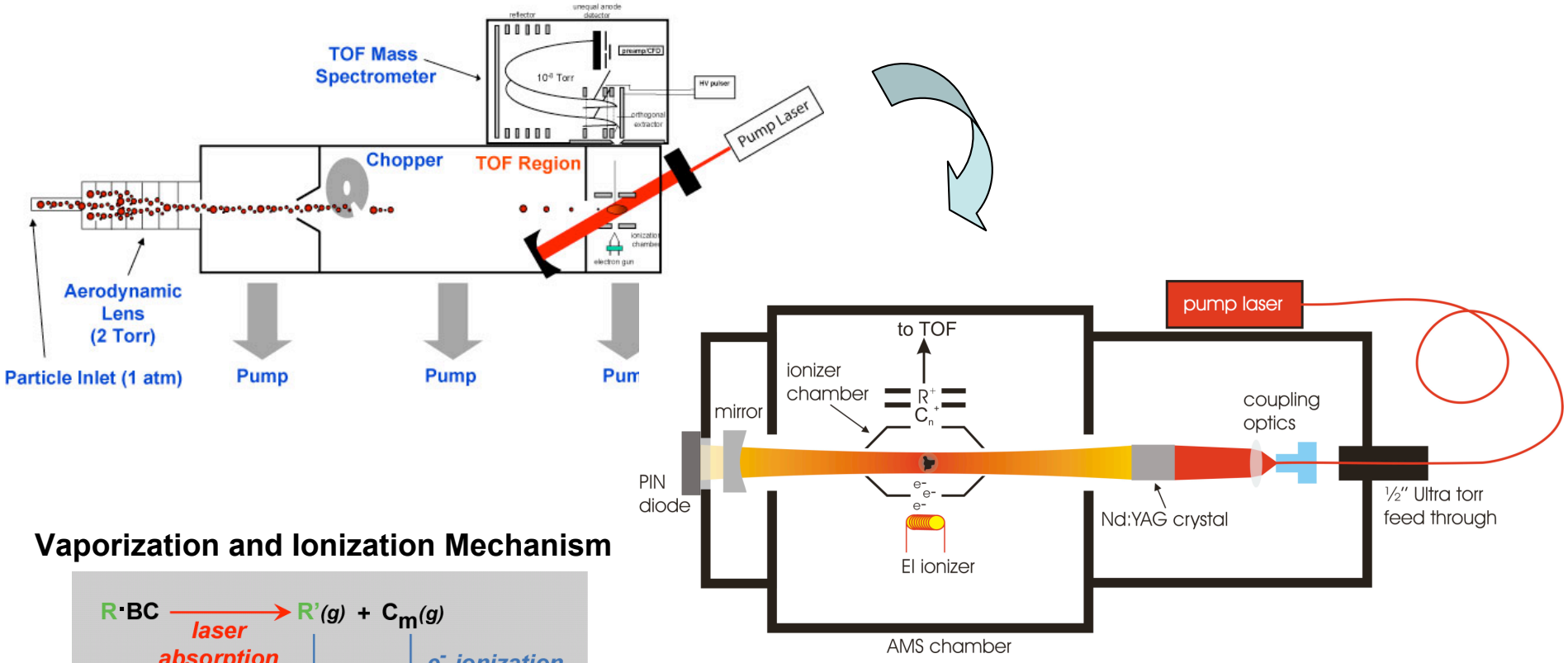
Instrument Development: SP2-AMS

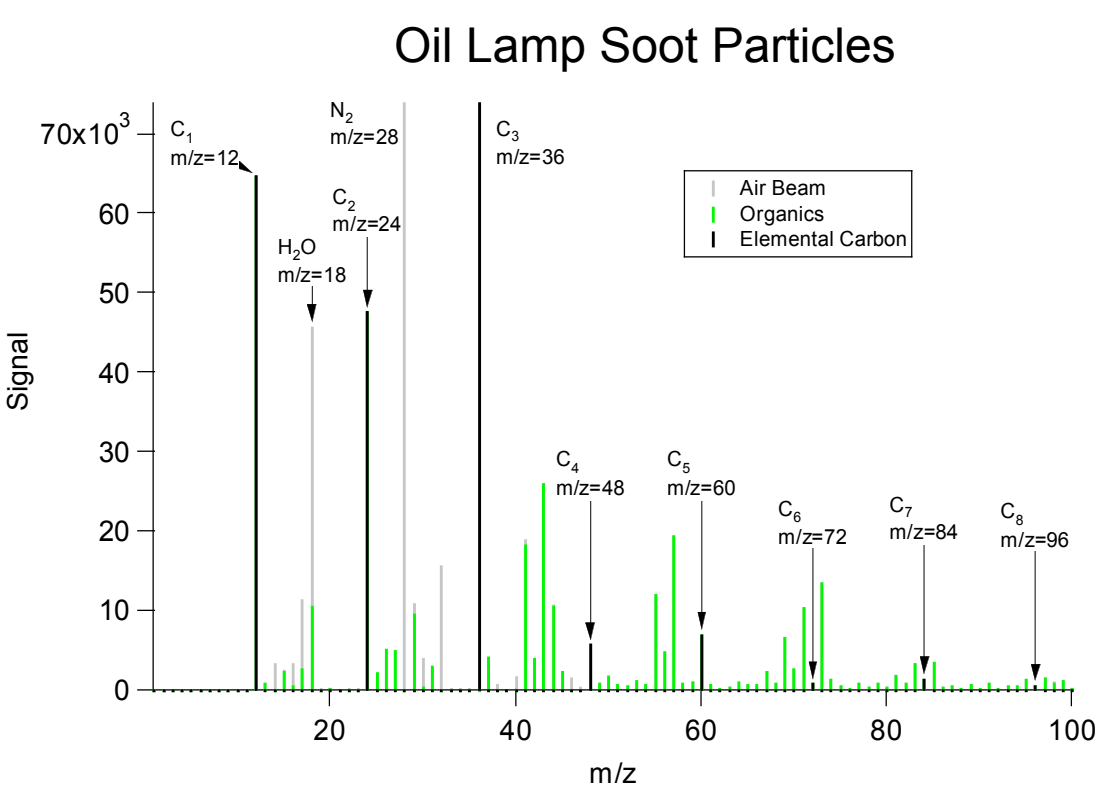


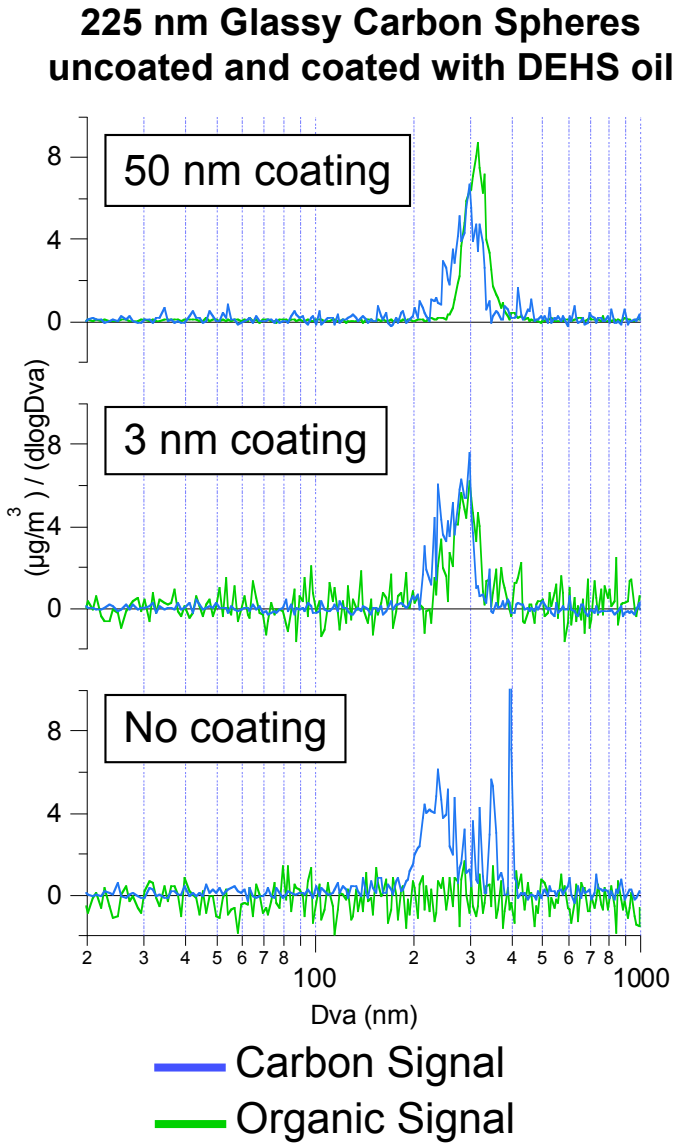
Vaporization and Ionization Mechanism

- Absorbing particles (coating and core) vaporize in laser
- Vapor is ionized by electron impact ionization
- Detection of the ions by Time-of-Flight mass spectrometry

in collaboration with Greg Kok at DMT

Chemistry, Mass, and Size of Coatings and Core





- Obtain chemical information on elemental carbon clusters and compounds coating the soot cores
- Mass signals are linear with respect to coating thickness and core size
- PTOF show size and particle mass signals increasing with particle coatings

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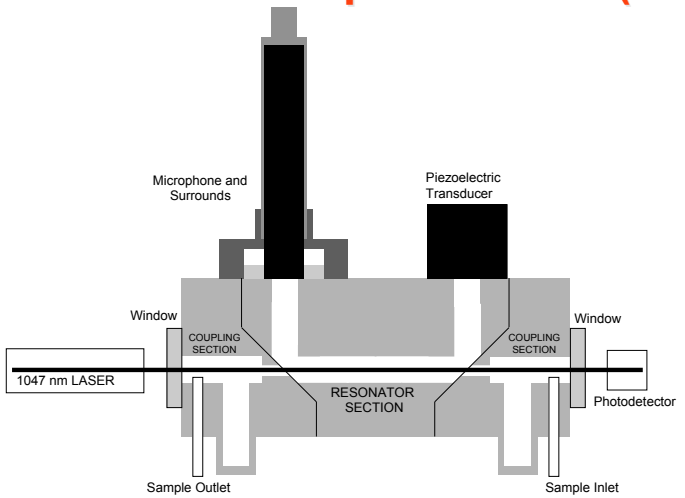
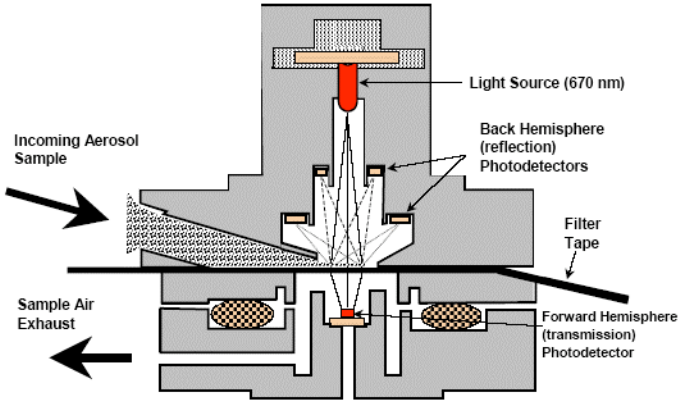
Inter-Comparison of Instruments Measuring Black Carbon Content of Soot Particles

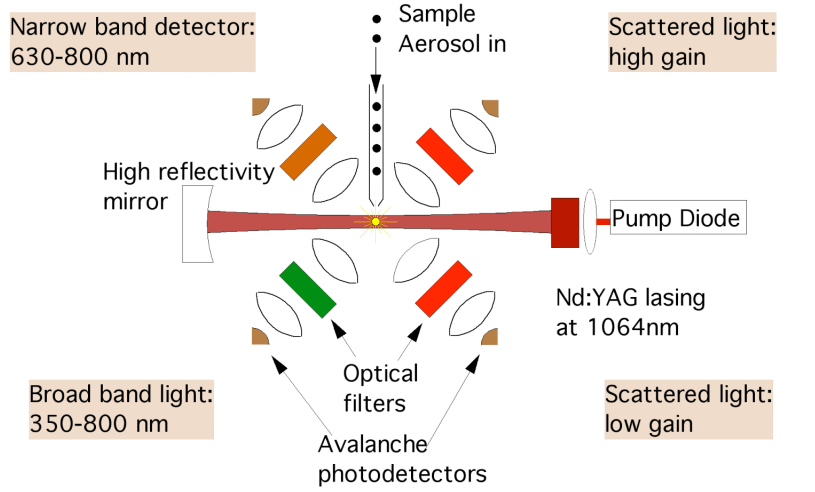
Photoacoustic Spectometer (PAS)



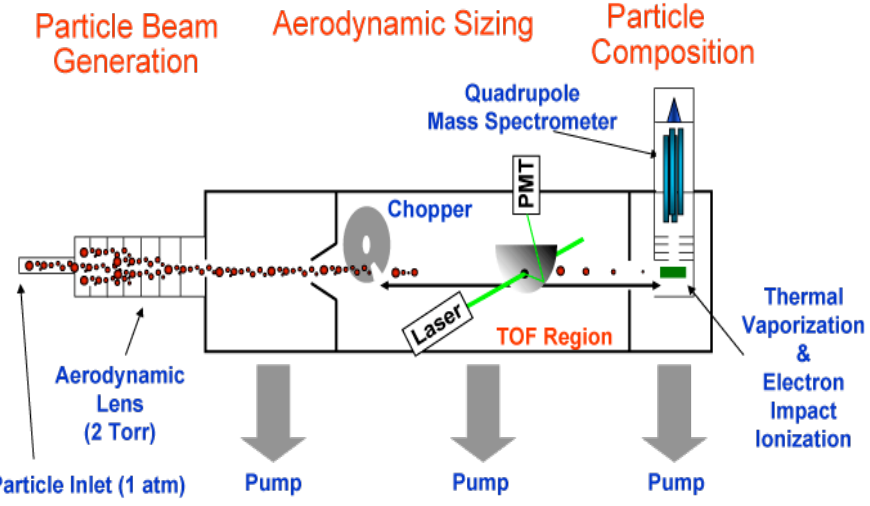
Multi-Angle Absorption Photometer (MAAP)



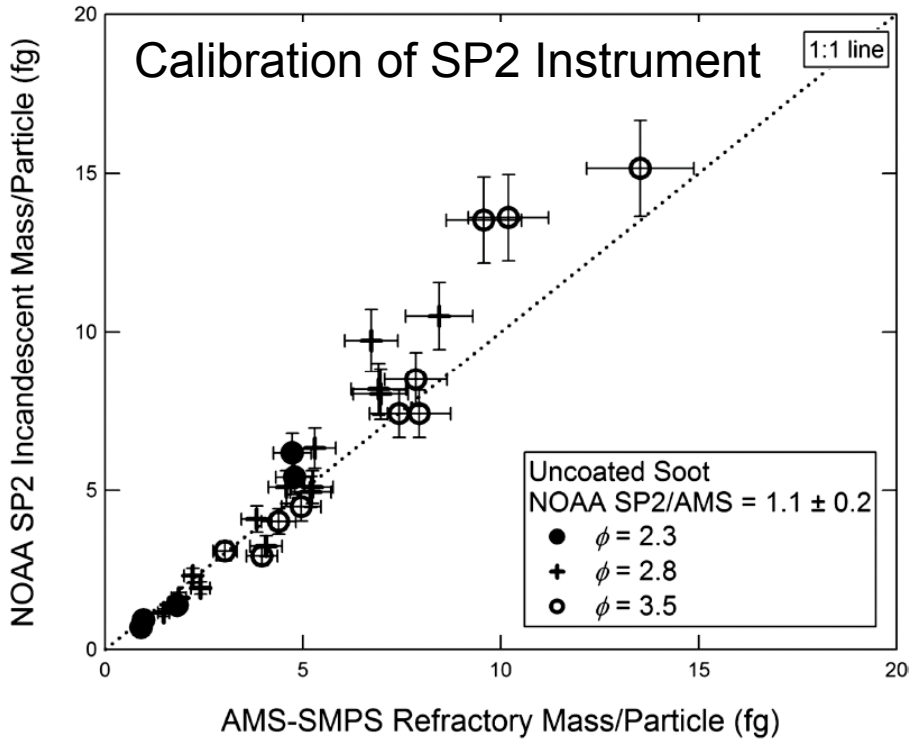
Single Particle Soot Photometer (SP2)

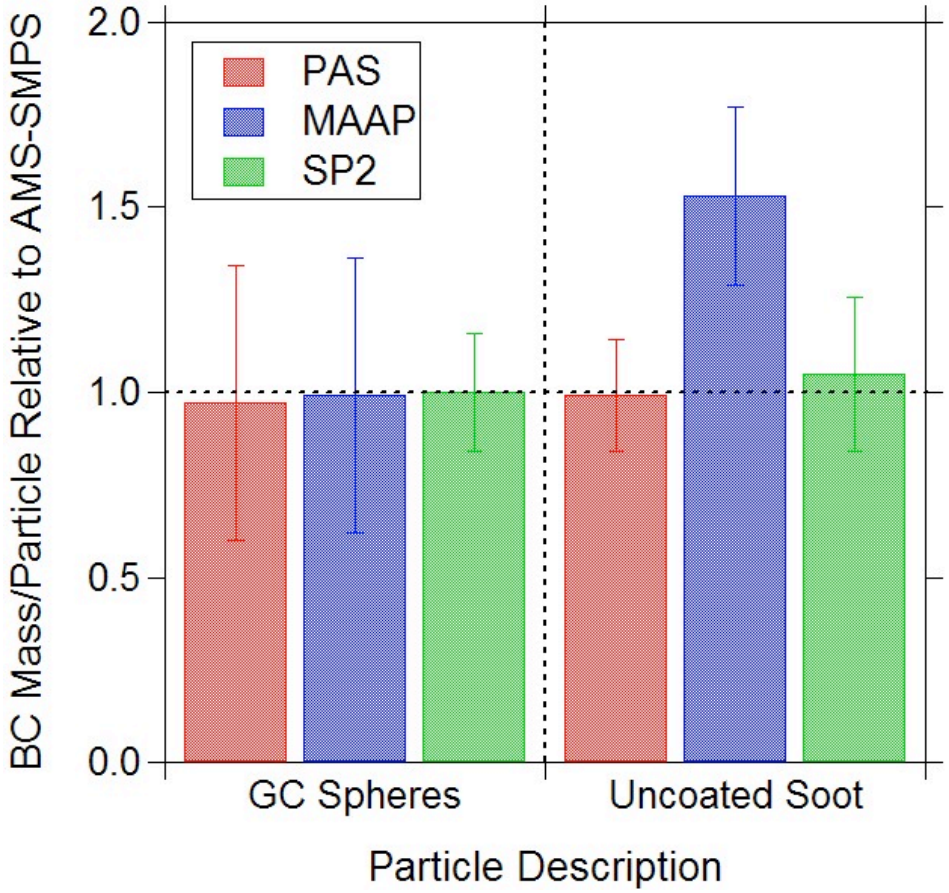


Aerosol Mass Spectrometer (AMS)



Instrument Comparisons





- Carbon spheres, uncoated flame soot, coated (liquid and solid) flame soot
- Flame equivalence ratios of 1.8 to 2.3
- Particle shape and solid coatings affected optical measurements

Slowik, J. G., E. S. Cross, et al. (2007). Aerosol Science and Technology 41: 295-314

Planned Black Carbon Measurements

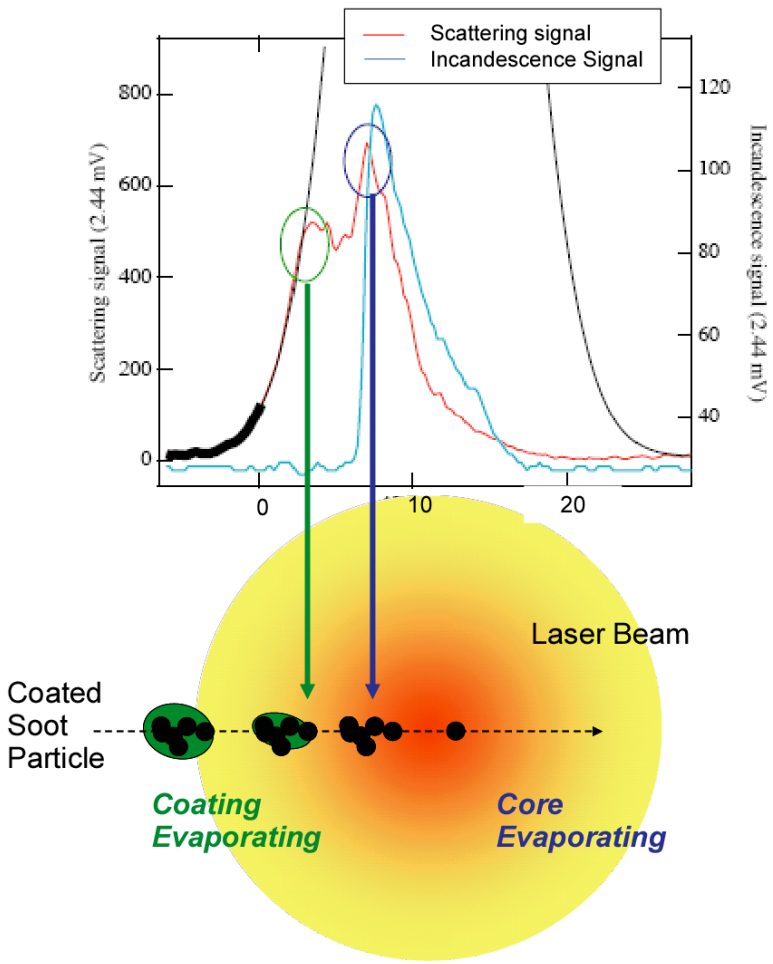
- Summer 2005 – initial BC study

- Summer 2008 – second Boston College laboratory study
  - Improved Flame Apparatus
  - Soot with equivalence ratios 1.8 to 5.0 (varying Dpp)
  - Thermal denuder
  - Condenser for organics and inorganics (sulfuric acid)
  - RH control in sampling lines
  - Instruments: SP2-AMS (Aerodyne/DMT), Photothermal Interferometric Absorption Spectrometer (Sedlacek/BNL), MAAP (Aerodyne), Photo-Acoustic Soot Spectrometer (DRI/LANL), SP2 (NOAA/DMT), OC/EC (?),

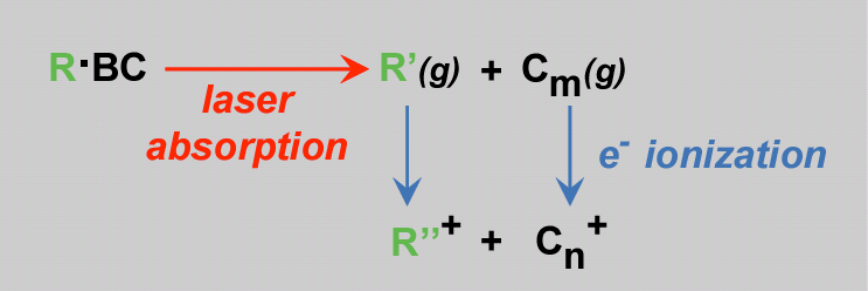
Summary

- Laboratory studies generating, modifying and characterizing carbonaceous soot particles
- CCN of mixed particles composed of soluble, slightly soluble, and insoluble components
- LS-C-TOF-AMS instrument development as a single particle aerosol mass spectrometer
- SP2-AMS instrument development for carbon particle chemistry, mass, and size measurements
- Black carbon instrument inter-comparison studies

SP2-AMS Sampling

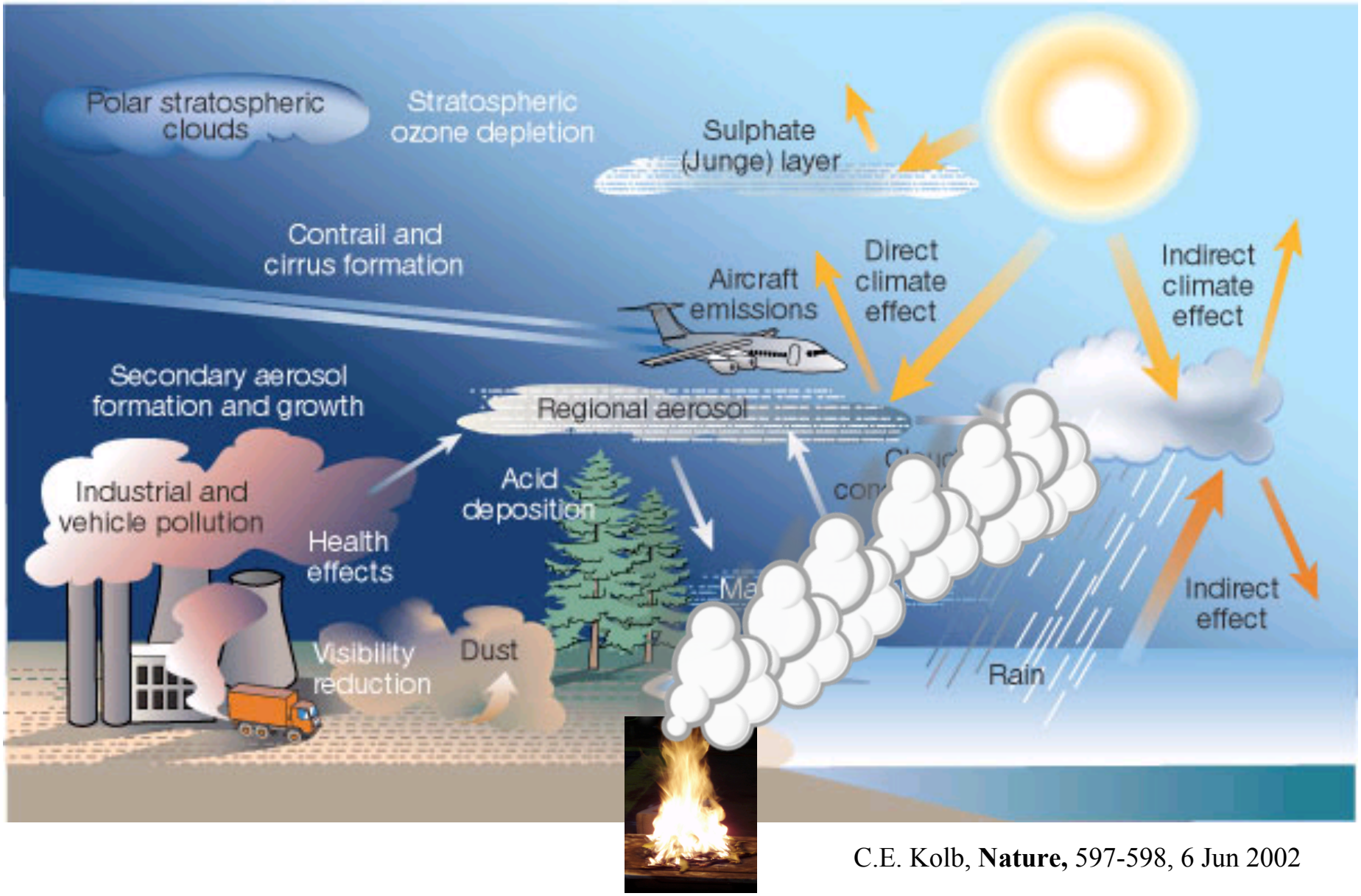


Vaporization and Ionization Mechanism



- Coatings evaporate first at relatively low temperatures (<600oC) potentially dependent upon vapor pressures
- Core evaporates last at high temperature (>1000oC) while incandescing (SP2)
- 5-20 microsecond evaporation time

Aerosols in the Atmosphere



C.E. Kolb, **Nature,** 597-598, 6 Jun 2002